Branly, Edouard. Radioconducteurs à contact unique. Pp. 347-349.

Meslin, Georges. Sur une forme de thermomètre électrique. Pp. 412-414.

Gonnessiat, F. Un second semestre d'observations météorologiques à Quito. Pp. 425-427.

Annuaire de la Société Météorologique de France. Paris. 50me Année.

Angot, A. Contribution à l'étude du régime pluviométrique de la France. Pp. 1-5.

Ciel et Terre. Bruxelles. 22me Année.

Rocquigny-Adanson, G. de. Époque de la floraison de l'Azalée pontique dans le centre de la France. Pp. 559-564.

Brückner, Ed. L'origine de la pluie. Pp. 565-570.

—— Les migrations d'oiseaux et le temps. Pp. 580-582.

Polis, P. Contribution à la climatologie des Hautes-Fagnes et de l'Eifel. Pp. 583-596.

L'Aérophile. Paris. 9me Année.

La Vaulx, Henry de. Expérience d'aéronautique sur la Méditerranée. Pp. 8-14.

Rostaing Lisboa, Carlos de. Description du ballon dirigeable "Aéronave Brazil." Pp. 14-23.

La Nature. Paris. 30me Année.

Rabot, Charles. L'hiver en Norvège. P. 154.

Zeitschrift für Gewässerkunde. Leipzig. 4 Band.

Kalecsinsky, A. v. Ueber die ungarischen warmen und heissen Kochsalzseen als natürliche Wärme-Accumulatoren, sowie über die Herstellung von warmen Salzseen und Wärme-Accumulatoren. Pp. 226-248.

Physikalische Zeitschrift. Leipzig. 3 Jahrgang.

Kossonogoff, J. Zur Frage der Dielektrika. Pp. 207-208.

Annalen der Physik. Leipzig. Vierte Folge. Band 7.

Stevens, E. H. Ueber Schallgeschwindigkeit in Luft bei gewöhnlicher und bei hoher Temperatur und in verschiedenen Dämpfen. Pp. 285-320.

Kalähne, Alfred. Ueber die Benutzung stehender Capillarwellen auf Flüssigkeiten als Beugungsgitter und die Oberflächenspannung von Wasser und Quecksilber. Pp. 440-476.

Illustrirte Aëronautische Mittheilungen. Strassburg. No. 1. 1902.

Linke, Franz. Die elektrische Ladung des Luftballons. Pp. 34-39.

Ebert, Hermann. Zusatz zu meinen Aufsatze "Magnetische Messungen im Ballon." Pp. 39-40.

Gaea. Leipzig. 38 Jahrgang. 1902.

—— Die warmen Salzseen von Szováta und die Quellen ihrer Wärme. Pp. 167-179.

Meteorologische Zeitschrift. Wien. Band 19.

Ekholm, Nils. Ueber Emission und Absoption der Wärme und deren Bedeutung für die Temperatur der Erdoberfläche. P. 1-26.

—— Preis-Ausschreiben. Pp. 26-27.

Hergesell, H. Veröffentlichungen der internationalen Kommission für wissenschaftliche Luftschiffahrt. Pp. 27-33.

Hergesell, H. Vorläufiger Bericht über die internationale Ballonfahrt am 5 September 1901. P. 34.

Hergesell, H. Vorläufiger Bericht über die internationale Ballonfahrt am 3 Oktober 1901. P. 34.

Hergesell, H. Vorläufiger Bericht über die internationale Ballonfahrt am 7 November 1901. Pp. 34-35.

Sieberg, Aug. Ein Beispiel für die Wirbelbewegungen in Cumulus-wolken. Pp. 35-37.

Hann, J[ulius]. Resultate der meteorologischen Beobachtungen am Sonnen-Observatorium Kodaikánal in Südindien 1900. Pp. 37-39.

Suschnig, G. Bericht über den III internationalen Wetterschiess-Kongress in Lyon. Pp. 39-40.

Mache, H. Beiträge zur Kenntniss der atmospärischen Elektricitäts-Beobachtungen in Indien und Oberägypten. Pp. 40-41.

—— Ergebnisse der meteorologischen Beobachtungen in Deutsch-Südwest-Afrika. Pp. 41-44.

Wolfer, A. Provisorische Sonnenflecken-Relativzahlen für das IV Quartal 1901. Pp. 44-46.

Journal de Physique. Paris. 4me Série. Tome 1.

Jansson. —. Sur la conductibilité calorifique de la neige. Pp. 121-122.

STUDIES ON THE STATICS AND KINEMATICS OF THE ATMOSPHERE IN THE UNITED STATES.

By Prof. FRANK H. BIGELOW.

II. METHOD OF OBSERVING AND DISCUSSING THE MOTIONS OF THE ATMOSPHERE.

INTRODUCTORY REMARKS.

It has been suggested to me that it would be advantageous to many who are interested in the progress of modern meteorology, if the results of the observations on clouds, which were made by the United States Weather Bureau during the years 1896-97, could be put in a more compact form than was adopted in the original report.[1]

I am the more inclined to present anew some of my results because of the extensive use that has been made of the American observations generally in Dr. J. Hann's Lehrbuch der Meteorologie, 1901. In this judicious and comprehensive summary of the state of meteorology at the end of the nineteenth century, Dr. Hann has given very generous recognition to the contributions of the United States, including the Weather Bureau and the Blue Hill Observatory, to the advancement of meteorology. But more important than this, the views therein adopted regarding the theories of the circulation of the atmosphere in the general and the local cyclones, are fully in accord with the ideas set forth in my report on the cloud observations of 1896-97. It is apparent that meteorology is at last securing a set of principles founded on observations, which will supersede much that has been heretofore taught in this connection. It is therefore important to explain the results of the Weather Bureau observations of 1896-97 as briefly and simply as possible.

Taking a very general view of the present state of meteorology, it may be proper to classify the conditions as follows: The statistical side of the subject is being rapidly worked up, so that our knowledge of facts is relatively quite complete in climatology, and in the diurnal and annual periods of the various atmospheric elements, namely, pressure, temperature, vapor tension, and wind direction, in different parts of the world, so far as they prevail in the strata near the ground. But in the upper strata our knowledge of these elements is still very limited, though it has been considerably extended during the past ten years, by the cloud observations, and the balloon and kite ascensions. On the theoretical side of static meteorology it may be said that meteorological analysis is well advanced, as far as concerns the barometric relations of pressure to the height, the temperature and vapor tension variations, and the adiabatic thermodynamics generally. The practical extension and application of these formulæ to the upper strata is making fair progress, and is likely to result in very definite knowledge of the true state of the atmosphere throughout its extent. In dynamic meteorology, however, that is in the hydrodynamics of the atmosphere, affairs are in an unsatisfactory condition, and they can be reclaimed only by pursuing a sound policy regarding them. Looking over the entire field, one is surprised to find that but little has been done in the preliminary and the most necessary stages of this work, in order to make the dynamics of the atmosphere a practical scientific problem. It is wasting time to speculate on the mathematical analysis of the motions of the atmosphere till we know what the motions are, simply as a case of kinematics. In other words, the paths of motion of the average air currents should be systematically worked up all over the world, as the indispensable preliminary to this study. Of course the obstacle in the way of doing this is the invisibility of the air itself, and the labor of making any observations on its direction and velocity of motion much above the ground. It was for supplying just this need that the international cloud observations of 1896-97 were instituted, and to it they have contributed a valuable amount of data.

Furthermore, there are the great physical problems connected with the absorption of the sun's radiant energy in the atmosphere, its separation into several kinds of energy—electric and magnetic energy, heat energy of the visible and invisible spectrum, and so on. Also there is the question to be answered as to the amount of the solar output itself, the variations from its mean value, how much and what kinds of energy are absorbed in the upper strata, and what in the lower. The circulation of the atmosphere in its details really goes back to these questions about which we know only a very little. Hence,

[1] Report on the International Cloud Observations, May 1 1896, to July 1, 1897, by Prof. Frank H. Bigelow. Report of the Chief of the Weather Bureau, 1898-99, Vol. II.

in a word, the deficiency of modern meteorology is in the dynamics of the upper and middle strata of the atmosphere.

NOTATION AND COORDINATES.

It is not an exceptional fact in the history of science that in the first stages of its development meteorology should have grown up in a rather haphazard fashion, especially as it was dealing with a subject of popular interest, wherein many observers were concerned in getting observations of one kind or another without much regard to their ultimate use in mathematical analysis. As the result of this lack of purpose the confusion became so great between the methods of observing and recording in different parts of the world that when comparative studies were begun the difficulties arising from the want of homogeneity were seriously felt. In order to remedy this state of confusion the International Meteorological Committee have been laboring for years to introduce uniformity into the methods adopted by meteorologists. Much has already been accomplished, and yet there are at least two very important steps that remain to be taken. The first is to use only one system of measures, as the metric in place of the metric and the English; and the second is to conduct and discuss the observations in such a way that in their published form they shall be in perfect order to meet the requirements of the fundamental mathematical equations, either static or dynamic, as they are needed. At present meteorological observations are about evenly divided between the English and the metric systems of measures, since the former is in use in Great Britain, Canada, United States, south Africa, Australia, and India; while the latter prevails in Europe, Asia generally, Japan, north Africa, and South America. Thus it is necessary to translate the figures from one system to the other in preparing the data for the world and for cosmical problems; also two sets of reduction tables are required for all the elements, and two sets of constants in all the formulæ. The more lamentable defect occurs from the fact that the observations are made without relation to their final use in mathematical discussions involving the motions of the atmosphere. Indeed almost nothing has been done to give us the true vector components of motion in the observations, so that they shall be in form for immediate introduction into the equations. The standard equations have been presented by different authors in many equivalent forms, and in consequence the subject has been made unnecessarily complex and difficult for students. The entire body of fundamental equations in meteorology is not very large, but the amount appears to be much greater than it really is by reason of the manifold notations and symbols which have been employed. No more valuable reform could be instituted than that of causing the same physical quantity to be always represented by the same symbol. Thus, for example, barometric pressure B, pressure in units of force P, pressure in units of weight p, would put us in harmony with the leading works in hydrodynamics and thermodynamics; then absolute temperature T, thermometric temperature t, mean temperature of the air column θ, vapor tension e, maximum vapor tension E, absolute weight of vapor μ, weight of the unit volume σ, specific weight ρ, and relative humidity $R.H.$ For rectangular coordinates, displacements (x, y, z) s, velocities (u, v, w) q, accelerations $(\dot{u}, \dot{v}, \dot{w})$ f, angular velocities $(\omega_1, \omega_2, \omega_3)$; for cylindrical coordinates, radius ϖ, angle about axis of rotation φ; for polar coordinates, radius vector r, polar distance θ, angle about axis of rotation λ.

I have felt the weight of these considerations in my comparative studies so much that special pains have been taken in my report to exhibit all the fundamental equations in a standard system of notation, and also to reduce the analyses of several authors to the same standard system for the sake of ready intercomparison. Also, as it seems to be of the utmost importance that the observations taken to determine the motions of the atmosphere should be made in a form appropriate for use in the dynamic equations without further transformation of the data, particular care was taken to make the cloud observations conform to these requirements. It was not possible to bring about this harmony between observations and the analytical theory without introducing some radical changes in the methods heretofore followed by meteorologists, both in the conduct of the observations and in the analytic development of the equations. Accordingly, some account of these changes, as well as of the new results which were deduced from the cloud observations made by the United States Weather Bureau in 1896–97, will be given in the following pages.

THE AXES OF COORDINATES.

The first decision that must be made in establishing a fundamental system of notation has regard to the choice of the axes of coordinates which shall be placed at the base of the entire study, since all the algebraic signs of the quantities depending on the observations which are to be substituted in the equations, must be determined from the adopted positive direction of the axes. This choice depends practically upon two facts, (1) that the radius of the earth is drawn positive outwards, since r increases from the center, and (2) that the right-hand rotation is adopted generally in modern scientific researches. It is true that some of the German mathematicians use the left-hand rotation, but the trend is toward a universal adoption of the right-hand system. If we take as the primary radius that of the earth's axis of rotation in the Northern Hemisphere, as is most appropriate for all scientific problems except in terrestial magnetism, then in polar coordinates the positive angular development in polar distance, θ, is southward; next, with the right-hand rotation about this axis extended upward, the positive development of λ, the angle in longitude, is eastward. Hence, for all systems of coordinates, polar, cylindrical, and rectangular, the azimuth rotation is *from the south through the east, north, and west.* Unfortunately this is in the opposite direction to the azimuth rotation adopted in astronomy, in navigation, and in popular meteorology, because in these branches of science the simple practical consideration has been to follow the sun in its diurnal course, so that azimuth circles and compass cards are numbered around in the clockwise or left-hand rotation. For many statistical purposes, as where average wind directions are to be computed, it makes little difference what system of notation is used, because these data do not look beyond their own immediate purposes. But where we have to deal with a system of equations it is not so. If we take the first set of equations, International Cloud Report (154), for linear velocities due to rotation,

$$\begin{aligned} u_1 &= u - y\,\omega_3 + z\,\omega_2 \\ v_1 &= v - z\,\omega_1 + x\,\omega_3 \\ w_1 &= w - x\,\omega_2 + y\,\omega_1 \end{aligned}$$

where x, y, z are linear distances, u, v, w are linear velocities, $\omega_1, \omega_2, \omega_3$ are angular velocities, it is evidently necessary that all these should be defined most carefully. According to the statement given above,

$+\ (x, u)$ are referred to the southward axis,
$+\ (y, v)$ are referred to the eastward axis,
$+\ (z, w)$ are referred to the zenithward axis,

but everything will go wrong if ω_3 is not taken to rotate positively about the axis z, from the south through the east, instead of through the west. Hence, ω_1 turns the axis of y to z, ω_2 the axis of z to x, ω_3 the axis x to y, in cyclical order. Thus it happens that, having adopted this system of rotation, it was found necessary to transform the equations of some well-known mathematical papers in dynamic meteorology to agree with it.

THE AZIMUTH ROTATION.

There is one further difficulty to overcome in regard to the popular meteorological system. An observer determines the direction of the wind by looking toward it and feeling the force of it on his face, or he sets up a wind vane with an arrow pointing in the direction *from which* it blows. This is, however, exactly contrary to the method that mathematical physicists employ, for they describe a stream line by the direction *toward which* it flows. An arrow is drawn on a map "down stream" to show how the current flows, or on the weather map an arrow is said to "fly with the wind." In the latter case meteorologists are inconsistent with themselves, but they adopt the correct principle in their precept on the map. If we describe a wind as having a velocity of so many miles per hour from a given direction, say the north, this must be changed in azimuth through 180° to the south in order to be of use in analytic work. We have thus to make *two reversals* in the common meteorological system: (1) the wind vector must be turned through 180°, and (2) the azimuth must be numbered from the south = 0° toward the east = 90°, north = 180°, and west = 270°. These two changes render it impossible to use the ordinary wind records which are found in meteorological reports without making this transformation. While it is not a very important matter for a few individual cases, it becomes a serious task to do the work of remodeling the figures for a large amount of data. It was for the purpose of saving this labor that the observations of the Weather Bureau were executed in 1896–97 on the correct system, so that all the figures appearing in the final report should be at once ready for use in the equations of hydrodynamics.

In order to facilitate the understanding of the discussion that follows, a chart is introduced to show the scheme of the operations. Fig. 1 gives a comparison of the azimuth system

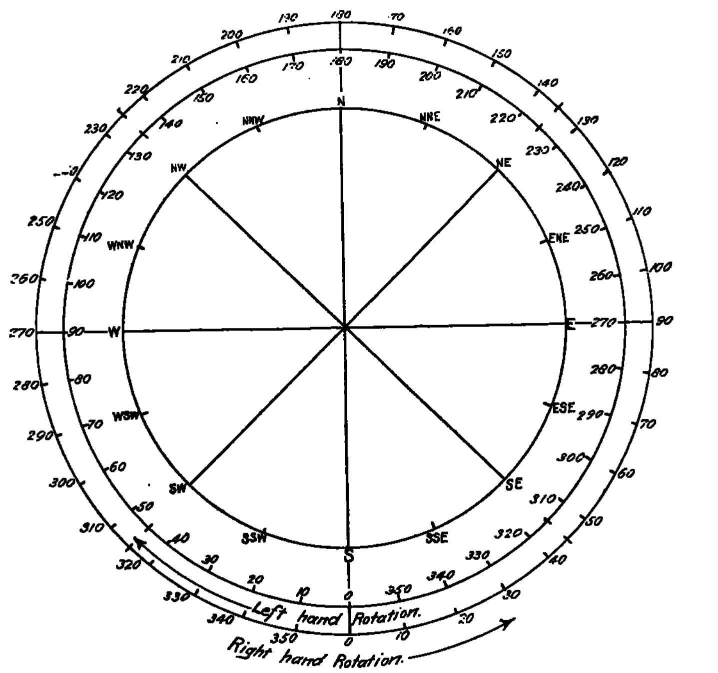

FIG. 1.—Comparison of the two azimuth systems.

Left-hand rotation gives azimuth of "motion from."
Right-hand rotation gives azimuth of "motion toward."
Positive translation is vertically upward.

commonly employed by meteorologists with the one adopted in this report. The former is the left-hand rotation, such as astronomers use, and is counted from the south through the west point of the horizon. In this system, also, the observer faces the wind and gives the azimuth of the direction *from which* it blows. This has been abandoned for the reasons already mentioned, and in place of it is substituted the right-hand rotation, wherein the azimuth is counted from the south through the east point. Here the observer receives the wind on his back and looks toward the direction in which the arrow flies and *toward which* the air is moving. Thus a wind *from the NW* by the former system, with azimuth angle 135°, becomes a wind *toward the SE*, with the azimuth angle 45°, by the latter system. The working out of the results by this system, ready for analytic discussion, as will be seen, involves a minimum of computation, and besides this it reduces all the velocity components to the fundamental rectangular system of coordinates adopted by Ferrel in his treatise, and continued in my "Standard System" which forms a part of the Report.

The Marvin nephoscopes, with which the observations were made, were all graduated to read in a right-hand (anticlockwise) azimuth; the theodolites were also read in the same direction, and the azimuths of Tables 6 and 9 of the International Cloud Report are, therefore, in accord with the coordinate directions of the formulæ which are developed in the following portions of the same Report.

THE COMPOSITION AND RESOLUTION OF THE VECTORS OF MOTION.

It is sometimes necessary to construct the resultant velocity and direction of the motion of the air at a given place out of a large number of individual observations, as in forming charts 20–35, International Cloud Report, for example, and the following practical devices were found convenient. Suppose it

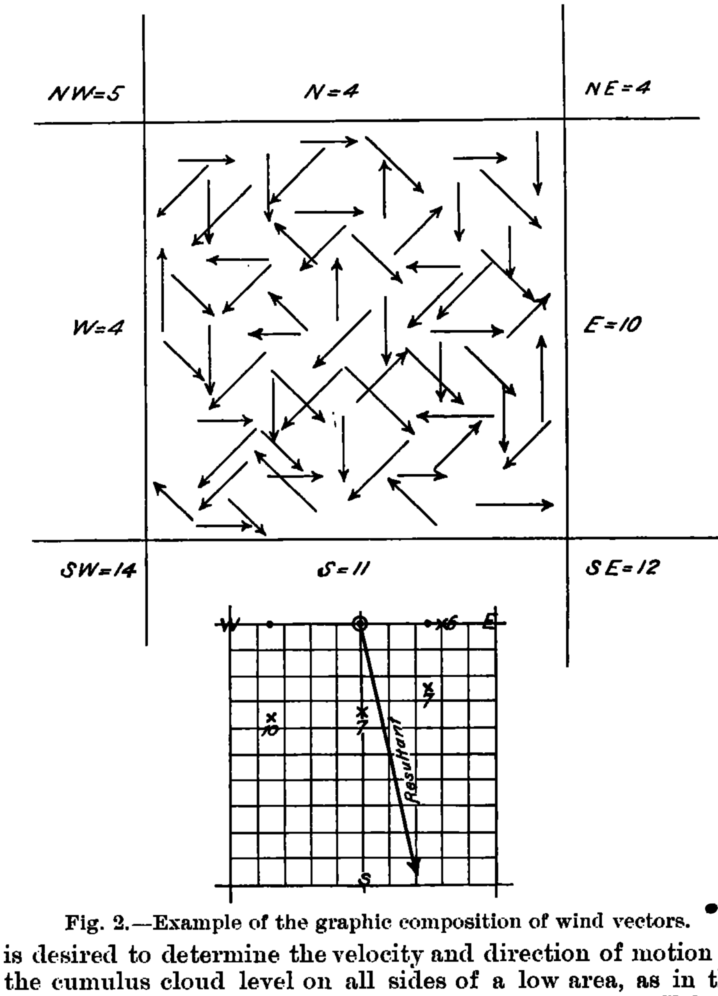

Fig. 2.—Example of the graphic composition of wind vectors.

is desired to determine the velocity and direction of motion in the cumulus cloud level on all sides of a low area, as in the Mississippi Valley. We can best proceed as follows: Take a piece of tracing paper, and select a large number of cloud maps showing about the same configuration of the isobars, so that the centers of the cyclones are located in a given district. Then lay the paper on the cloud maps in succession, and trace the arrows showing the cloud motion wherever an observation is found on the map. Mark the center on the first map and preserve it so as to place it in coincidence with the other cyclonic centers. Continue to fill the paper till some such composite of arrows is obtained as is shown within the square of fig. 2. A scale map of squares, or any other adopted division of areas, is to be prepared as large as the tracing paper, and the two are placed together so that the scale diagram marks off the arrows of the composite map into groups, within each of which it is proposed to find the resultant. Then count out the number of arrows pointing N, NE, E, etc., in succession for eight directions, giving in our example, N=4, NE=4, E=10, etc.; take the excess in four directions, as S = 7, E = 6, SE = 7, SW = 10; plot these results on a diagram and resolve SE = 7 into E = 5 and S = 5; also SW = 10 into W = —7 and S = +7; make the sums E = +4 and S = +19; plot these components and obtain the resultant V=20; the angle φ=9° can be found by the use of a circular protractor, or it can be computed by the formula $\tan\varphi=\frac{E}{S}$, having regard to a change of algebraic signs for W = —E and N = —S

Wind vector.	Component.	
	E	S
S=7	......	+7
E=6	+6	......
SE=7	+5	+5
SW=10	—7	+7
	+4	+19

$$V = 20;\ \varphi = 9°,\ \text{that is,} = \text{S } 9° \text{ E.}$$

$$\tan\varphi=\frac{E}{S}=\frac{4}{19}=0.21.$$

It is easy to perform a large amount of graphic composition in a short time after a little practise, by arranging this work systematically. In the collection of vectors from the maps the total number will differ from square to square, and it is necessary to reduce the resultant to a common standard number. Suppose we adopt 40 arrows as the standard, then the completed resultant velocity must be reduced in that proportion. Our example contained 64 arrows, hence $20 \times \frac{40}{64} = 12$, and 12 is to be adopted as the average velocity of the motion in the azimuth 9°, that is, S 9° E. These resultants assume that the average of a number of observed directions gives a *relative* velocity of motion, which can be reduced to an absolute velocity as soon as the true mean motion is determined from some other source, as by theodolite observations. Charts constructed in this way are quite correct as to the direction of the motion of the atmosphere, and they give the relative velocities in different parts of a cyclone or anticyclone with sufficient precision to permit further important studies.

By the nephoscope observations the actual velocities in different portions of the area surrounding the center of motion were computed and collected for the several subareas about the highs and lows, as explained in chapter 7 of the International Cloud Report. The relative velocities there recorded can be turned into actual velocities by utilizing the corresponding theodolite observations. The nephoscope refers all the observed motions to the 1000-meter plane, and the theodolite to the actual plane of motion at the height given by the angular measurements. I note that Dr. J. Hann, in his Lehrbuch der Meteorologie, pages 272, 273, and 275, attributes certain cloud heights of the Weather Bureau observations to the nephoscopes, but this is a mistake, because all our heights were determined by the theodolites. The heights associated with the nephoscope observations were adopted for translating the relative velocities of the nephoscopes into actual velocities, and his impression doubtless arose from printing such adopted heights in conjunction with the other data which were derived from nephoscopes.

THE RESOLUTION OF FORCES.

In the study of the motions of the atmosphere at all levels there are two types of resolution of vectors to be provided for in the discussion, the first in rectangular coordinates,

$$+x = \text{South},\ +y = \text{East},\ +z = \text{zenithward},$$
$$-x = \text{North},\ -y = \text{West},\ -z = \text{nadirward},$$

in order to apply them to the motions of the general circulation over the entire hemisphere; and the second in cylindrical coordinates,

$+x$ = radial outward,
$-x$ = radial inward,
$+y$ = tangential counter-clockwise,
$-y$ = tangential clockwise,
$+z$ = vertical upwards on the axis,
$-z$ = vertical downwards on the axis, the results being used in the analysis of cyclones and anticyclones, that is in the local circulations. It is evident that the vectors provided by the theodolite and nephoscope observations, in the form V = velocity and φ = azimuth counted from the south through the east, are ready for simple trigonometric resolution into the velocity coordinates (u_1, v_1) in the four quadrants by using the proper signs. When all the vectors (V, φ) are resolved in the north-south and west-east directions, we can take the mean values by summation and then compute the average motion of the entire mass of air circulating at a given altitude over any locality. It is necessary to obtain these mean directions of motion for the entire circulation, in order to be able to resolve out the special components of local circulation belonging to the cyclones and anticyclones. In the report on the International Cloud Observations the results of this rectangular resolution of the observed mean vectors are set forth in Table 33 as a summary; in Tables 34, 35, and 36 for high areas in the northern and southern portions of the United States; in Tables 38, 39, and 40 for the low areas in the northern and the southern portions of the United States; in Tables 42 and 43 the component southward and eastward velocities in highs and lows, also in selected areas; and in Tables 48, 49, 50, and 51 the seasonal velocities in the upper and lower cloud levels. This data bears directly upon the problem of the upper air currents in the general circulation, and similar data ought to be obtained in all portions of the world.

These rectangular, meridional, and longitudinal velocity components are marked u_1, v_1 in order to distinguish them from the cylindrical components which are designated u_2, v_2. Having constructed the individual components of general motion u_1, v_1 in all the subareas together with the corresponding normal velocities, it is evident that the algebraic differences between them gives the true cyclonic and anticyclonic components, still in rectangular coordinates, as in Tables 44 and 45. The next step is to transform them into cylindrical coordinates u_2, v_2 with the least possible labor. For this purpose it is important to select the subareas surrounding the center of a local circulation in such a manner as will contribute to that purpose. If the areas marked out by the 5° meridians and parallels of latitude are taken, it is impossible to transform the component velocities without a most tedious computation. Such areas are suitable for a simple display of the stream lines, but they do not readily lend themselves to the composition and resolution of vectors of motion.

I have, therefore, adopted the following plan for the subareas surrounding a center of motion. They each have about the same relative area, and they are distributed as far as possible on the cardinal lines of the compass direction. They are numbered with the right-hand rotation, and they are central each on some cardinal point of the compass. Thus on the north-south line 17, 9, 3, 1, 5, 13 are located; on the west-east line 19, 11, 4, 2, 7, 15 are found; while 18, 10, 6, 14 run from NW to SE, and 20, 12, 8, 16 from SW to NE. Hence it is seen that all the N-S and W-E areas are immediately available for composition in rectangular and in cylindrical coordinates, while the rectangular coordinates of the NW-SE and SW-NE areas which come from the first collection need only a simple transformation to become the radial and tangential components of cyclonic circulation. These latter are to be ultimately worked out, and we shall then have three sets of coordinates arranged symmetrically about the center

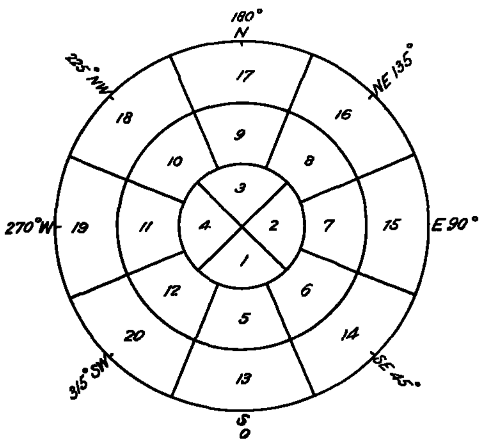

FIG. 3.—Plan of the subareas, azimuths, and compass points, adopted in high and low areas, for the discussion of cloud observations.

The mean of areas 1 to 4 = I, at the average distance 250 km.
The mean of areas 5 to 12 = II, at the average distance 750 km.
The mean of areas 13 to 20 = III, at the average distance 1,250 km.

of the three circles I, II, III at certain evenly distributed distances. The scale of the original diagram, Chart 9, International Cloud Report, is on a radius of 3 centimeters; on the weather maps this is equivalent to 15 centimeters, where 1 cetimeter is equal to 100 kilometers. The adopted scale is therefore *one-fifth* the scale of the daily weather map, and on it 1 centimeter represents 500 kilometers or 310.7 miles, and one millimeter is equivalent to 50 kilometers, or 31.1 miles. All the diagrams of the Report, as far as possible, are reproduced on this scale, but they are readily interpreted on the weather map, so far as linear dimensions are concerned.

VECTORS OF MOTION IN HIGH AND LOW AREAS—RECTANGULAR COORDINATES.

In order to prepare the observations for discussion all those which were made in the same subarea of a cyclone or an anticyclone were collected together in each cloud stratum, and the resultant of all these individual vectors was computed in accordance with the method above described. The individual observations occur in Table 9, and the mode of collecting them is illustrated in Table 29, page 363 of the Report. For convenience, the United States was divided into six districts: 1, Alberta; 2, Lakes; 3, New England; 4, Colorado; 5, West Gulf; 6, South Atlantic; so as to arrive at a conception of the prevailing local characteristics. Hence the heading of the form H—2—15, occurring in several tables, means that in subarea 15, of a high area or anticyclone whose center is in the Lake district, the accompanying observations were made in the several cloud strata, and also at the surface where the instrumental meteorological data are given at the three daily observations. Table 32 contains the resulting vectors V, φ for the northern and southern groups by districts, also for the four seasonal quarters of the year, together with the several mean values, all this extending to the eight cloud strata. In this table the relative velocities are given as derived from the nephoscope, that is on the 1,000-meter plane.

The vectors of Table 32 are plotted on Chart 13 of the Report, the northern in red and the southern in blue, first for the high areas and then for the low areas; also in the seasonal groups so that the comparative motions can be studied. It is evident that several years work are needed to produce smooth and evenly balanced mean vectors, which shall truly represent the average circulation. Especially it will be necessary for the Canadian stations to cooperate and supply the vectors wanting in the northern subareas of our three northern districts, as this part of the circulation usually extends into Canada. Furthermore, the vectors of Table 32 are collected together numerically in Tables 34 to 40, with a single change, namely, that the velocities observed on the 1,000-meter plane have been multiplied by the adopted mean height of the given cloud stratum. For example, the mean height of the cirrus is taken as 9.8 kilometers, and hence the mean annual velocity $V = 3.6$ of the cirrus in high area No. 1., page 368, is multiplied by 9.8, and it is entered at the beginning of Table 34 as $V = 35.3$. I have taken the cirrus in each subarea of the high and low areas to show as an example in Table 1 and fig. 4.

TABLE 1.—*Direction and velocity of motion in high and low areas—rectangular coordinates.**

Compass Point.	Area number.	Cirrus; average height 9.8 kilometers.					
		High.			Low.		
		No.	φ	V	No.	φ	V
S	1	25	86	35.3	7	111	51.0
E	2	16	57	43.1	4	96	40.2
N	3	49	76	31.4	..	...	....
W	4	30	78	36.3	6	104	58.8
S	5	37	66	37.2	50	97	31.4
SE	6	20	67	32.3	33	101	44.1
E	7	23	90	58.8	10	109	36.3
NE	8	43	89	29.4	..	...	....
N	9	51	81	34.3	7	90	49.0
NW	10	34	117	38.2	3	92	27.4
W	11	42	80	37.2	23	77	45.1
SW	12	12	107	14.7	6	105	56.8
S	13	38	95	31.4	27	123	33.3
SE	14	64	82	35.3	70	93	32.3
E	15	28	100	46.1	49	85	34.3
NE	16	58	85	28.4	24	90	30.4
N	17	27	88	36.3	..	...	....
NW	18	25	96	33.3	2	122	39.2
W	19	51	98	29.4	36	71	44.1
SW	20	63	109	30.4	94	90	41.2
No. of obs....		736	...	....	451	...	....
Means		...	...	34.9	...	...	40.8

*Extracts from Tables 34 and 38.

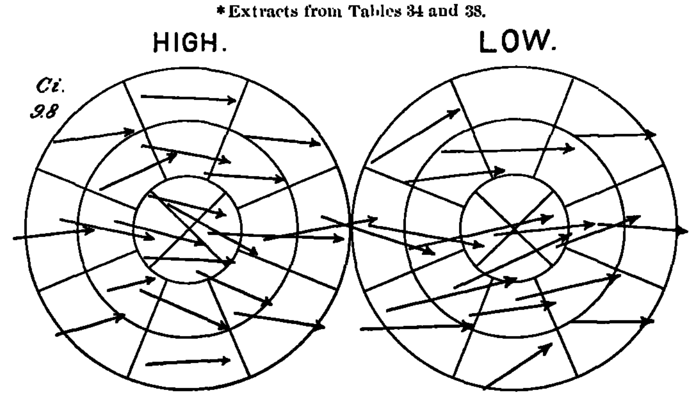

FIG. 4. (From Chart 15.)

These vectors are plotted on Chart 15 (see fig. 4), which shows the annual vectors on the several cloud levels in high and low areas. From Chart 15 and the Tables 34–40 are obtained the data for discussing the mean general circulaton over the United States. The mean total velocities in high and low areas, without regard to direction, are found by taking the mean of the velocities in the areas of Tables (34–40) and they are given in Table 33, section 1, as in the following example, Table 2:

TABLE 2.—*Total velocities in highs and lows without regard to directions.**

Clouds.	High areas.				Low areas.		
	Height, kilom.	All groups.	Northern.	Southern.	All groups.	Northern.	Southern.
Ci	9.8	34.9	38.3	30.4	40.8	44.6	28.3
Ci. S	9.8	39.1	42.6	34.8	39.8	42.5	36.3
Ci. Cu	8.1	33.5	33.9	30.5	39.3	43.8	34.8
A. S	5.9	30.2	31.1	24.1	36.0	39.4	30.5
A. Cu	4.5	23.5	26.6	19.7	29.2	32.6	24.4
S. Cu	2.5	23.3	22.7	18.5	28.6	32.9	21.1
Cu	1.5	11.2	10.9	10.4	14.6	17.4	11.8
S	0.9	11.4	12.2	9.5	11.1	13.2	8.6
Wind	0	4.8	4.9	4.8	5.4	5.3	5.9
Range, per ct	....	....	....	19	15	....	28
From Table	....	34	35	36	38	39	40

*Extract from Table 33, Section I.

TABLE 3.—*General rectangular components of motion in high and low areas.**

Compass point.	Area number.	Cirrus, average height 9.8 kilometers. High. S+	High. E+	Low. S+	Low. E+
S	1	+ 2.5	+35.2	—18.3	+47.7
E	2	+23.5	+36.2	— 4.2	+40.0
N	3	+ 7.6	+30.5	....	....
W	4	+ 8.6	+35.5	—14.2	+57.0
S	5	+15.1	+34.0	— 3.8	+31.2
SE	6	+12.6	+29.7	— 8.4	+43.3
E	7	0.0	+58.8	—11.8	+34.3
NE	8	+ 0.5	+29.4	....	....
N	9	+ 5.4	+33.9	0.0	+49.0
NW	10	—17.3	+34.0	— 1.0	+27.4
W	11	+ 6.4	+36.6	+10.1	+43.9
SW	12	— 4.3	+14.1	—14.7	+54.9
S	13	— 2.7	+31.3	—18.1	+27.9
SE	14	+ 4.9	+34.9	— 1.6	+32.3
E	15	— 8.0	+45.4	+ 3.0	+34.2
NE	16	+ 2.5	+28.3	0.0	+30.4
N	17	+ 1.3	+36.3	....	....
NW	18	— 5.2	+33.1	—20.8	+33.2
W	19	— 4.1	+29.1	+14.4	+41.7
SW	20	— 9.9	+28.8	0.0	+41.2
Means		+1.97	+33.7	—5.26	+39.4
Normals		**— 1.6**	**+36.6**	**— 1.6**	**+36.6**
Means		+0.66	+40.1	—3.75	+32.7

* Extract from Tables 42 and 43.

Table 2 shows that the velocities are greater in the northern circuit than in the southern, and greater in the low areas than in the high areas. These values must be studied in connection with the barometric gradients to form a theory of the dynamic action in the atmospheric circulation.

The vectors in the form velocity and azimuth, V, φ, are next resolved into rectangular components in the north-south, west-east direction by the trigonometric rules, and the results are given in Tables 42, 43, from which the example in Table 3 is taken.

The means of these components are taken out in two ways: (1) the algebraic mean which gives the rectangular coordinates of motion in the general circulation for the highs and the lows, respectively. The mean of these last forms the normals from which the true cyclonic components are computed, and they are printed in heavy faced type. These results are collected together in Table 33, Sections II and III, from which the following extract is made, Table 4:

TABLE 4.—*Southward and eastward components of velocities in highs and lows.**

Clouds.	High areas. +S —N	High areas. +E —W	Low areas. +S —N	Low areas. +E —W	Means. North.	Means. East.
Ci	+ 1.97	+33.7	— 5.26	+39.4	— 1.6	+36.6
Ci. S	+ 1.65	+32.0	— 9.24	+35.9	— 3.8	+34.0
Ci. Cu	— 0.60	+32.6	— 3.00	+37.2	— 1.8	+34.9
A. S	— 0.37	+27.2	— 4.60	+31.3	— 2.5	+29.2
A. Cu	— 0.07	+22.1	— 2.38	+24.3	— 1.2	+23.2
S. Cu	— 0.32	+16.0	— 4.00	+24.3	— 2.2	+20.2
Cu	— 0.13	+ 5.1	— 0.11	+11.4	— 0.1	+ 8.3
S	— 1.22	+ 5.8	— 1.32	+ 7.8	— 1.3	+ 6.8
Wind	— 0.69	+ 1.1	— 0.40	+ 1.5	— 0.5	+ 1.3
From Table	42	42	43	43	....	....

*Extract from Table 33, Sections II and III.

TABLE 5.—*Component velocities in selected areas between high and low centers.**

Clouds.	Selected areas. Southward. H. 16, 8, 2, 7, 15, 6, 14 L. 18, 10, 4, 11, 19, 12, 20		Northward. L. 16, 8, 2, 7, 15, 6, 14 H. 18, 10, 4, 11, 19, 12, 20	
Ci	+ 0.66	+40.1	— 3.75	+32.7
Ci. S	— 2.11	+36.9	— 3.89	+38.9
Ci. Cu	+ 4.95	+38.7	— 7.34	+32.1
A. S	+ 2.79	+26.5	— 7.47	+31.0
A. Cu	+ 6.24	+23.7	— 7.78	+21.9
S. Cu	+10.22	+22.1	—11.13	+17.1
Cu	+ 6.52	+ 9.6	— 8.13	+ 6.5
S	+ 5.25	+ 7.5	— 7.97	+ 5.1
Wind	+ 2.23	+ 3.2	— 3.25	+ 0.2
Range	....	....	....	....
From Table	42	42	43	43

*Extract from Table 33, Section IV.

The most important remark to be made regarding these extracts is that the observations show an average northern component in the United States in all levels, provided it is a fact that as much air streams through the low areas as through the high areas on the average. (2) The subareas were collected into two groups, those having a southward and those having a northward component. Thus we have a southward component in high areas in 16, 8, 2, 7, 15, 6, 14, and in low areas in 18, 10, 4, 11, 19, 12, 20; but a northward component in high areas in 18, 10, 4, 11, 19, 12, 20, and in low areas in 16, 8, 2, 7, 15, 6, 14. The means from these groups give the mean components of the distinctly southward and northward currents in the different strata. They are collected in Table 33, Section IV, and are reproduced in Table 5:

TABLE 6.—*Anticyclonic and cyclonic components, cirrus 9.8 kilom.**

HIGH AREAS.

Area No.	Rectangular components.				Cylindrical components.	
	u_1	v_1	σ	β	u_2	v_2
1	+ 4.1	— 1.4			+ 4.1	— 1.4
2	+25.1	— 0.4			— 0.4	—25.1
3	+ 9.2	— 6.1			— 9.2	+ 6.1
4	+10.2	— 1.1			+ 1.1	+10.2
5	+16.7	— 2.6			+16.7	— 2.6
6	+14.2	— 6.9	15.7	333	+ 4.9	—14.9
7	+ 1.6	+22.2			+22.2	— 1.6
8	+ 2.1	— 7.2	7.5	286	— 6.6	+ 3.6
9	+ 7.0	— 2.7			— 7.0	+ 2.7
10	—15.7	— 2.6	16.0	190	+13.2	— 9.2
11	+ 8.0	0.0			0.0	+ 8.0
12	— 2.7	—22.5	22.8	263	+14.0	—18.0
13	— 1.1	— 5.3			— 1.1	— 5.3
14	+ 6.5	— 1.7	6.8	345	+ 3.4	— 5.9
15	— 7.4	+ 8.8			+ 8.8	+ 7.4
16	+ 4.1	— 8.3	9.2	296	— 8.7	+ 3.0
17	+ 2.9	— 0.3			— 2.9	+ 0.3
18	— 3.6	— 3.5	5.0	225	+ 5.0	0.0
19	— 2.5	— 7.5			+ 7.5	— 2.5
20	— 8.3	— 7.8	11.4	223	0.0	—11.4

LOW AREAS.

Area No.	Rectangular components.				Cylindrical components.	
	u_1	v_1	σ	β	u_2	v_2
1	—16.7	+11.1			—16.7	+11.1
2	— 2.6	+ 3.4			+ 3.4	+ 2.6
3	......	......			......	......
4	—12.6	+20.4			—20.4	—12.6
5	— 2.6	— 5.4			— 2.2	— 5.4
6	— 6.8	+ 6.7	9.6	136	— 0.1	+ 9.6
7	—10.2	— 2.3			— 2.3	+10.2
8	......	......	....	...	......	......
9	+ 1.6	+12.4			— 1.6	—12.4
10	+ 0.6	— 9.2	9.3	274	+ 6.1	+ 7.0
11	+11.7	+ 7.3			— 7.3	+11.7
12	—13.1	+18.3	22.6	127	—22.5	+ 3.2
13	—16.5	— 8.7			—16.5	— 8.7
14	0.0	— 4.3	4.3	270	— 3.0	— 3.0
15	+ 4.6	— 2.4			— 2.4	— 4.6
16	+ 1.6	— 6.2	6.4	285	— 5.5	+ 3.2
17	......	......	....	...	......	......
18	—19.2	— 3.4	19.6	190	+16.1	—11.3
19	+16.0	+ 5.1			— 5.1	+16.0
20	+ 1.6	+ 4.6	5.0	70	— 2.2	+ 4.6

*Extracts from Tables 44, 46 and 45, 47.

It is important to note that the most rapid currents, both northward and southward in the atmosphere, are in the strato-cumulus level, 2.5 kilometers or 1.6 miles above the ground, and that these currents decrease in velocity above and below that level. The eastward velocity averages about the same in the highs and lows. Hence we infer that the strato-cumulus level is the stratum where the interchanging motion is most rapid between the Tropics and the poles.

VECTORS OF MOTION IN HIGH AND LOW AREAS—CYLINDRICAL COORDINATES.

We can now compute the true cyclonic and anticyclonic rectangular components by simply subtracting the normal values (heavy type, Table 3) from the individual subarea values in each cloud stratum. In this way the components u_1, v_1 of Tables 44, 45 are found, and an example is given above, in Table 6, in the cirrus level for the high and low areas. Against subareas 6, 8, 10, 12, 14, 16, 18, 20 there are placed the corresponding vectors (σ, β), velocity and azimuth, because these are needed in resolving the rectangular into cylindrical components. In the other subareas the components are already in the N–S and W–E directions and they can be transformed by mere inspection into the corresponding cylindrical coordinates, which are radial and tangential to a circle about the central axis, and they give u_2, v_2, as in Table 6, and fig. 5 following, in which $+ u_1 =$ southward, $+ v_1 =$ eastward, $+ u_2 =$ radial outward, $+ v_2 =$ tangential anticlockwise.

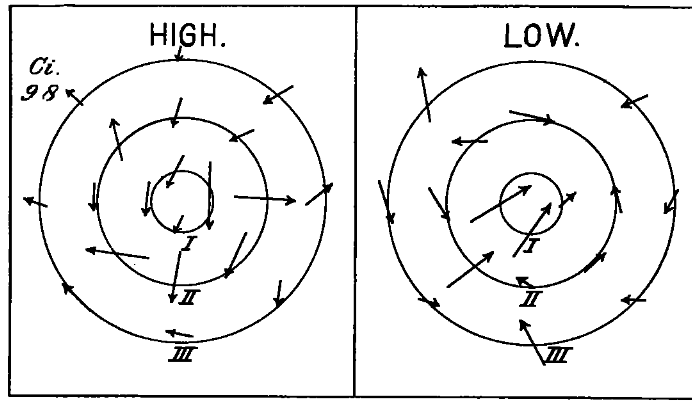

FIG. 5. (From Chart 16.)

Those which do not lie on the north-south west-east lines are transformed as follows: The coordinates u_1, v_1 are compounded into the vector (σ, β), σ being the linear distance from the center, and β the angle from the south. Thus in cirrus 6, high, Table 44, $u_1 = 14.2$, $v_1 = -6.9$, and we find $\sigma = 15.7$, $\beta = 333°$, which can be verified by reference to Chart 16 *a*. In the same way all the vectors under subareas 6, 8, 10, 42, 14, 16, 13, 20 which lie on the SE–NW and NE–SW diagonals have been reduced to vectors (σ, β).

To reduce these to the cylindrical coordinates, we subtract 45° from β in 6 and 14, 135° from β in 8 and 16, 225° from β in 10 and 18, 315° from β in 12 and 20. Then the vector [σ ($\beta - \alpha$)] is resolved at once into u_2, v_2. Thus 15.7, 333° of Ci. 6, high, Table 44, becomes 15.7, 288°; thence $u_2 = 4.9$ $v_2 = -14.9$, as in cirrus 6, high, Table 46, and as can also be verified on the Chart 16 *a*. In this way the coordinates of the anticyclonic and cyclonic components, Tables 46, 47, have been found. We have thus the data in such form that one more concentration can be made. If we assume that a symmetrical gyratory circulation is represented by the coordinates of Chart 16, it is now necessary simply to take the mean values of the cylindrical coordinates lying on each circle; that is to say, the mean of the areas 1–4, 5–12, 13–20, respectively. This has been done, and they are entered as I, II, III, in the next section of the same Tables 46, 47. The means of I, II, III, themselves, are also entered on the next line, as average values for the entire circulation in each cloud level. These can be most conveniently studied by reference to Charts 17, 18, where specimen vectors are plotted for the several levels.

The rectangular components were transferred to Chart 16 and drawn so that the vectors shall be central on the circles I, II, III, which run through the middle of the respective adopted subareas. In order to get some idea of the average cyclonic and anticyclonic vectors in the different levels, the mean values of the vectors found on the circles I, II, III, respectively, were taken, and these give the relations between the inner and the outer portions of the masses of air in motion in cyclones and anticyclones. They are shown in Charts 17 and 18. To secure one more concentration of the data, and to further eliminate the local defects, the nine levels were reduced to three by taking the means of the three upper, the the three middle, and the three lower strata together, respectively, and these are shown on Chart 19. The following small Table 7 gives the corresponding numerical results; it is Table 52 of the cloud report.

TABLE 7.—*Mean components grouped in three levels.**

MEAN ANTICYCLONIC COMPONENTS.

		I.	II.	III.
Upper level.	u_2	− 3.3	+ 3.9	+ 2.2
	v_2	− 4.5	− 5.2	− 4.8
Ci., Ci. S., Ci. Cu.	σ	5.6	6.5	5.3
	β	234	307	294
Middle level.	u_2	0.0	+ 4.2	− 0.8
	v_2	− 7.1	− 6.6	− 9.3
A. S., A. Cu., S. Cu.	σ	7.1	7.9	9.3
	β	270	303	265
Lower level.	u_2	+ 3.3	+ 3.0	+ 1.8
	v_2	− 4.1	− 7.0	− 6.2
Cu., S., Wind.	σ	5.3	7.6	6.4
	β	308	294	287

MEAN CYCLONIC COMPONENTS.

		I.	II.	III.
Upper level.	u_2	− 1.2	− 6.8	− 1.8
	v_2	+10.2	+12.3	+ 0.7
Ci., Ci. S., Ci. Cu.	σ	10.3	14.0	2.0
	β	96	119	161
Middle level.	u_2	− 7.3	+ 0.3	+ 1.6
	v_2	+18.6	+14.4	+ 5.2
A. S., A. Cu., S. Cu.	σ	20.0	14.4	5.5
	β	111	89	73
Lower level.	u_2	+ 0.3	− 2.4	− 1.5
	v_2	+ 7.9	+ 6.3	+ 3.8
Cu., S., Wind.	σ	8.0	6.7	4.2
	β	88	111	112

* Copy of Table 52.

It is evident that it would be of great advantage to meteorology to have similar observations continued systematically in the United States, so as eventually to obtain perfectly reliable vectors of motion throughout the atmosphere, and they should be extended to all parts of the world as rapidly as practicable. It is not very safe to draw conclusions extending to the entire atmosphere from the observations made at a few selected localities, such as those in the United States or Europe, but it seems to be necessary for us to do so in the present incomplete state of meteorology. Moreover, we must use the material we now have in discussing what are the fundamental principles of dynamics that can be admitted into the theory, and accordingly I shall proceed to take up the observed general circulation and the local circulations, and compare them with the existing theories in order to arrive at such views as will probably determine the theoretics of the dynamic meteorology of the future.

NOTES AND EXTRACTS.

MR. C. F. R. WAPPENHANS.

Mr. Carl F. R. Wappenhans, for many years a member of the Signal Corps and of the Weather Bureau, died at Arco, Switzerland, February 4, 1902. Mr. Wappenhans was born at Berlin, Prussia, in 1834, served as an officer in the United States Navy from 1862 to 1868, joined the Signal Corps on January 9, 1871, was placed on the retired list as first class sergeant on December 28, 1891, was appointed local forecast official in the Weather Bureau on the same date, and resigned on August 31, 1901. He was in charge of the station at Indianapolis, Ind., from January 30, 1871, until the date of his resignation, with the exception of four years, from 1879 to 1882, when he was in charge of Detroit, Mich. Mr. Wappenhans was a man of most kindly and genial disposition, and a faithful and efficient official.—*H. E. W.*

THE WEATHER OF THE MONTH.

By Prof. ALFRED J. HENRY, in charge of Division of Records and Meteorological Data.

CHARACTERISTICS OF THE WEATHER FOR FEBRUARY.

The weather of February, 1902, was much like that of February, 1901. In the interior low temperatures and great dryness prevailed while on both coasts the precipitation was above the seasonal average. A remarkable feature of the month was the persistence of a ridge-shaped area of high pressure that extended from Tennessee northwestward evidently beyond the field of observation. This ridge of high pressure seems to have been formed and maintained by the movement southeastward along the eastern slope of the Rocky Mountains in British Columbia of areas of high pressure of rather small extent, yet sufficient to prevent areas of low pressure from crossing the Rocky Mountains in the neighborhood of the forty-eighth parallel of latitude. All of the storms of the month therefore except the last one moved southeasterly over the Plateau region to the Texas coast, thence easterly along the Gulf coast, and northeastward along the Atlantic coast to New England. As in 1901 a great depression persisted over the North Atlantic off the Canadian Maritime Provinces. Pressure was also remarkably low off the north Pacific coast and the rainfall in that region was extraordinarily heavy. The temperature was